CHAPTER 8

CONTROL OF PRODUCTS IN PIPELINES

INTERFACE CONTROL

Pipelines between bulk terminals are multiproduct lines. Problems caused by pumping more than one product through a pipeline involves mixing of the products and disposing of the mixed portions (interfaces). The progress of the different products and the interfaces must be followed so that the products can be taken off the line at the right place. The volume of interfaces depends on differences in gravity and viscosity of adjacent products and on the pressure and velocity of the stream. It also depends on the interior condition of the pipe, the number of pump stations, and the distance traveled by the interface. The differences in gravity and viscosity will also effect interface disposal. Interface size can be reduced by maintaining a pumping rate needed to keep the heaviest product in the line in turbulent flow. The size also can be reduced by putting products in the line in proper batching sequence and by keeping the line pressurized during a shutdown. Positive pressure will prevent the speed of the interface and the interface volume will be cut down whether the interface stops on level ground or on a slope**.** Principles of pipeline hydraulics are covered in Appendix C, page C-7.

FLOW OF PRODUCTS

The two types of flow in a pipeline are laminar flow and turbulent flow (Figure 8-1, page 8-2). Laminar flow is a smooth, streamlined flow in which product in a pipeline will flow in concentric layers. Turbulent flow occurs when the velocity of flow increases beyond critical velocity and the layers disintegrate. The two types of flow can be shown by pumping a colorless liquid into a glass pipeline. A colored liquid is then injected into the pipeline. The flow can be observed at points downstream. At low velocities, the color seems to flow in streaks or straight lines (A, Figure 8-1, page 8-2). The streaks are actually concentric layers. This arrangement of layers is referred to as laminar flow. As velocity increases, laminar flow continues until the streaks waver and break into a slightly different pattern (B, Figure 8-1, page 8-2). This is the point of critical velocity. At velocities higher than critical, the streaks are dispersed at random throughout the stream (C, Figure 8-1, page 8-2). This is referred to as turbulent flow. In both types of flow, stream velocity varies from zero at the pipe walls to a maximum at the center (D and E, Figure 8-1, page 8-2). The mean velocity of laminar flow is 0.5 of the maximum velocity. The mean velocity of turbulent flow is about 0.75 of the maximum velocity. The velocity curve flattens in turbulent flow. In batching products, this shows how much less the tail product penetrates the head product in turbulent flow than in laminar flow. If the pipeline is kept in turbulent flow at all times, a smaller volume of interface is formed.

USE LIMITS

The disposition of interfaces is determined by product use limits. Off-specification products whose qualities fall within established use limits still may be used for their intended purposes. The extent to which a product can be safely thrown off specification determines how much adjacent product can be blended with it. MIL-HDBK-200 is the guide for application of use limits.

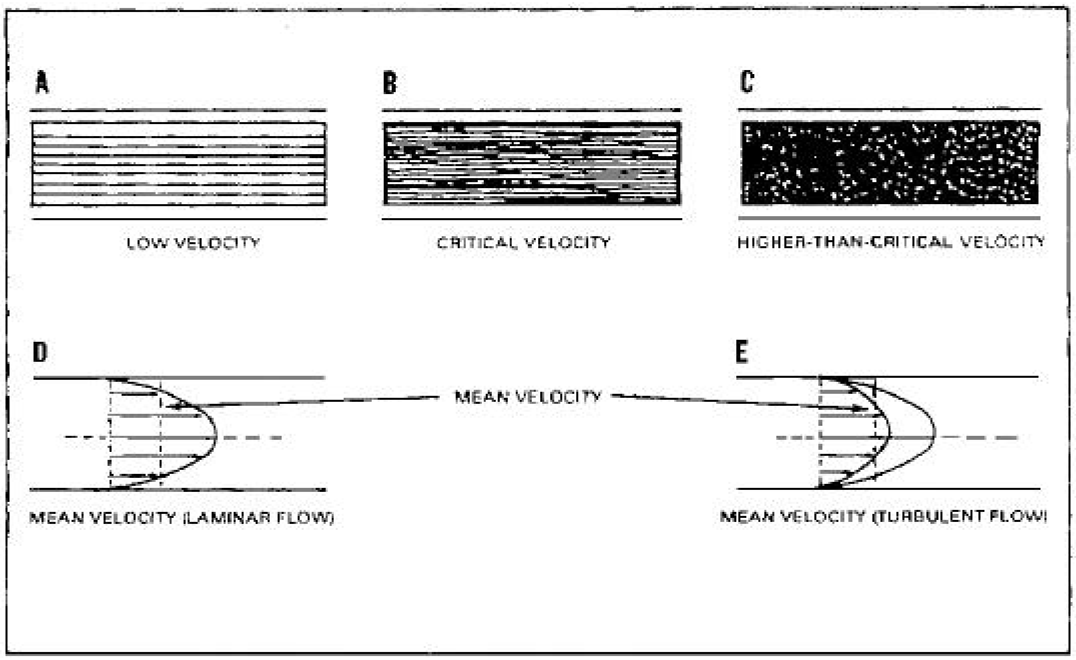

Figure 8-1. Laminar and turbulent flows

BATCHING PROCEDURES

Products likely to be batched in military multiproduct pipelines include MOGAS, kerosene, jet fuels, and diesel fuel (Figure 8-2, page 8-3). Exact batching sequences are not fixed. However, batches should be arranged to protect critical products and to produce interfaces that can be used. Closely related products are adjacent in descending or ascending order of quality or gravity. Products most closely related in quality have the least difference in gravity. They form interfaces that spread less with distance traveled. Also, they are most easily disposed of in one or both of the adjacent fuels. This method of batching simplifies quality surveillance. Disposal of interfaces is also simplified by making heart cuts for deliveries along the line. Heart cuts are portions of pure product taken from the line before and after the interface at intermediate terminals. When heart cuts are made, the final terminal for any product is the only place where interfaces are handled. When a complete batch is taken off at an intermediate point, the interfaces must be taken off also. The preceding and following batches are then brought together with as little mixing as possible. The quality surveillance officer or chief dispatcher gives instructions on disposing of interfaces. Batch identification, batch changes, and batch residue are described below.

BATCH DESIGNATION

Product code numbers form the first part of a numerical batch designation. The batch number forms the second part. For example, 1-21 is the batch designation for the twenty-first batch MOGAS pumped since the first of the fiscal year. Product code numbers in a pumping sequence may be in numerical order (Figure 8-2, page 8-3). Batch numbers are assigned for each fiscal year, beginning with number one for the first batch of any fuel. Pump stations record the numbers of passing batches at all times. The time of each batch change is recorded and reported to the dispatcher.

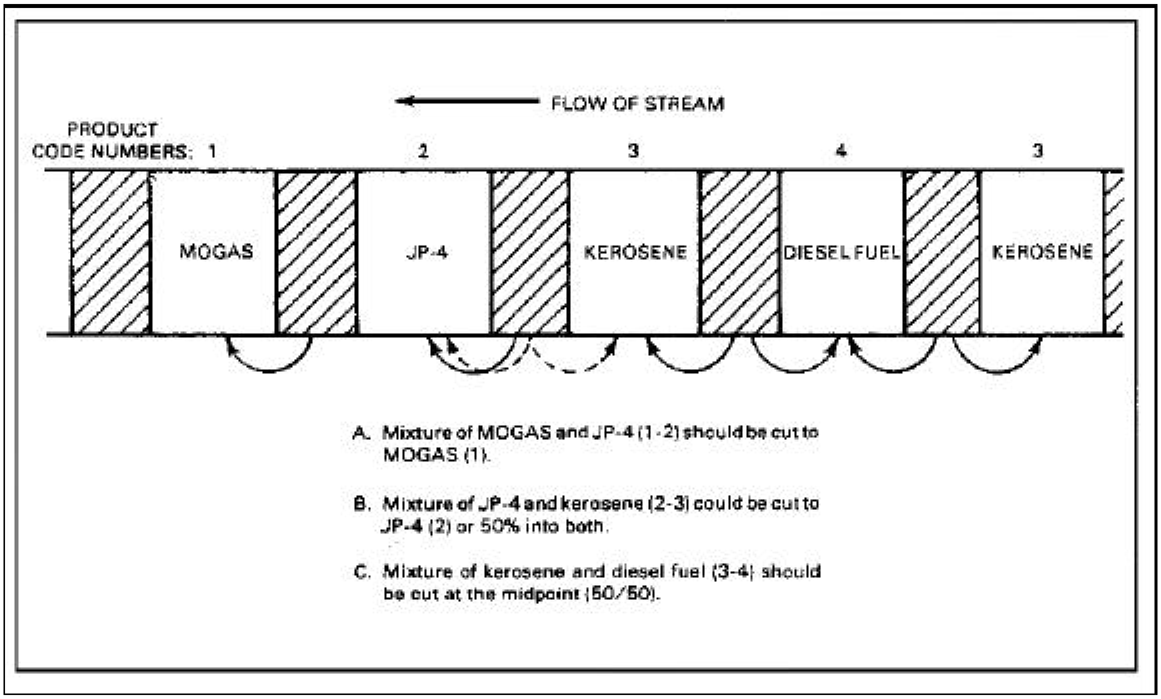

Figure 8-2. Pumping sequence for batching fuels

DETECTION OF BATCH CHANGES

In control of product flow through the pipeline, it must be determined where one batch ends and another batch begins. The following methods are used to detect batch changes in the pipeline.

- Gravity Difference. Batch changes may be detected by differences in gravity of two adjacent products. There may be a great difference, as between MOGAS and JP-8. There may be little difference, as between DF-1 and DF-2 (Figure 8-3, page 8-4).
- Color Change. Batch changes may be detected by differences in color of two adjacent products. There may be a great difference in color or almost no difference.
- Liquid Buffers. Kerosene or some neutral product (in a relatively small amount) may be used as a liquid buffer to separate incompatible products. Water is not used to separate products.
- Physical Buffers. A physical buffer is an object, such as a pig, rubber ball, or scraper constructed entirely of polyurethane, placed in the line to separate batches and cut down on the interface.
- Dye Plug. A plug of dye is injected into a line to separate like products belonging to different customers. Also, it is used to separate similar products with little or no color differences, such as DF-1 from DF-2.

BATCH RESIDUES

After deliveries and in idle pumps or stations after shutdowns, fuel stays in delivery lines, dead ends of pipes, and manifolds. Pipe 6 5/8 inches in diameter holds about 1½ gallons per foot. Fuel in delivery lines should be displaced as much as possible before new deliveries are started. Pumps and pump manifolds of an idle station may have 5 or 6 barrels of fuel. This residue should be kept current with changing batches so that it is not pumped into the line at the wrong time. A pump or pump station not on the line should be started up just before each batch changes and idled through the change to flush the system.

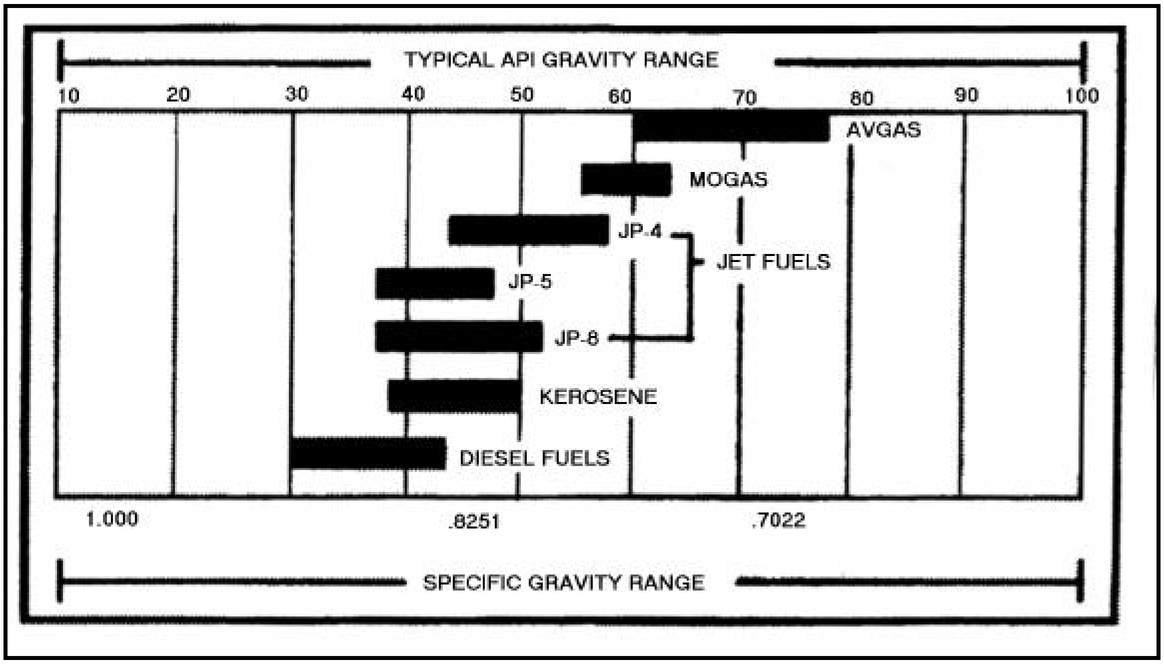

Figure 8-3. API and specific gravity scale for petroleum products

SWITCHING PROCEDURES

Protection of product specifications in the pipeline system begins in the lines leading into the base terminal. Before product is received, these lines should be freed of product received earlier. It can be displaced by the fuels to be discharged from the next tanker. Water should not be used to displace fuels in sea unloading lines. There must be a clean interface when a new product is started in the pipeline. At this point, the dispatcher is interested in the total amount of the preceding product pumped into the line and an opening gage on the new product. The opening gage is made before the switch. The closing gage on the old product is made immediately after the switch. As a rule, flying switches are made in batch changes. When interface arrives, an operator closes one tank valve while another operator opens a tank valve on another tank, making a heart cut. This is a precision operation. The period of time in which both valves are open must be as short as possible. However, one valve must be opened before the other is closed.

DELIVERY PROCEDURES

The interface lengthens quickly as it first starts downstream in the pipeline. The farther it travels down the line, the more slowly it lengthens. About 65 percent of the total interface between two products will occur in the first 20 percent of pipeline distance. The dispatcher gives each station the expected arrival time of the interface. Each station reports the first through the final change of color or gravity at one-minute intervals across the interface. Deliveries to storage or to branch pipelines at intermediate points should be made from heart cuts. The main concern of the station is setting the proper valves and determining when the interface has passed. When the sampler opens the delivery valve or branch line, fuel is taken off at the rate and time directed by the dispatcher. Flying switches are used in deliveries. However, the method of disposing of interfaces may complicate the switching procedure at a final station.

PRODUCT CUTS

There may be times when product cuts are needed. A number of factors must be considered when making such cut. There are three ways to dispose interfaces. These ways depend on the type of batch change. They are as follows:

- All of the mixture is cut into one or the other of the adjacent products. This protects critical products and creates usable interfaces. The dispatcher should determine percentages of each product in the interface to be cut into the adjacent products.
- The mixture is divided between the two adjacent products, usually at the mid-gravity point. This provides minimum contamination for both products if blending tolerances are considered. Dispatching personnel should determine percentages of each product in the interface to be cut into the adjacent products.
- The whole interface is taken off the line into a slop tank and is blended with incoming products later. This mixture becomes a new product with its own identity. Dispatching personnel should determine the percentages of product in slop tanks that are to be used in blending.

DETERMINING TIME OF CUT

The type of batch change being made determines the right time to make the cut. A line sampling station may be a distance upstream from the pipeline manifold. This distance is equal to a specific time interval, usually about 15 minutes at the normal rate of flow. The interval is not specified, but it should be known because it represents the time available to prepare for the cut. Also, the interval determines the actual time of the operation,

Preparing for Color Change

While preparing for a color change, the sampler should take a sample from the line before the change is expected. Beginning with the sample in which the first change is noted, successive samples are taken at one-minute intervals. These samples are arranged in the order taken so that a definite time can be fixed for the first and final change.

Preparing for Gravity Change

When preparing for a gravity change, the terminal operations officer or the dispatcher gives the station the corrected API gravities of the two products. These gravities are converted to the gravities at the existing line temperature. This gives the complete gravity range through which the batch change will take place. The gravities must be converted each time the line temperature changes. Observed gravities and the times are recorded from the first change to the final change (Figure 8-4, page 8-5).

Station: Petersburg, VA Date: 18/11/XX Line temperature: 56°F

FROM:
Product: Kerosene Batch No 5-21
Observed gravity: 42.0 API
Corrected gravity: 42.3 API
Time of first change: 2019

TO:
Product: Gasoline Batch No 4-26
Observed gravity: 60.7 API
Corrected gravity: 61.2
Time of last change: 2040

Note: The first sample recorded is the last taken before the first change.

Number	Time Taken	Observed Gravity	Corrected Gravity	Number	Time Taken	Observed Gravity	Corrected Gravity
1	2017	42.0	42.3	20	2037	59.6	60.1
2	2019	42.2	42.5	21	2038	60.1	60.6
3	2020	42.5	42.8	22	2039	60.5	61.0
4	2021	43.3	43.6	23	2040	60.7	61.2
5	2022	44.2	44.5	24	2041	60.7	61.2
6	2023	45.2	45.5	25			
7	2024	46.2	46.6	26			
8	2025	47.4	47.8	27			
9	2026	48.6	49.0	28			
10	2027	49.8	50.2	29			
11	2028	51.0	51.4	30			
12	2029	52.2	52.6	31			
13	2030	53.4	53.8	32			
14	2031	54.6	55.0	33			
15	2032	55.7	56.1	34			
16	2033	56.6	57.0	35			
17	2034	57.5	57.9	36			
18	2035	58.2	58.7	37			
19	2036	59.0	59.5	38			

Remarks: Takeoff started at 2100
Pumping rate: 2,800 BPH

Figure 8-4. Batch change record based on gravity readings and time intervals

Preparing for Color And Gravity Change

When preparing for a color and gravity change, color and gravity are observed before the expected time of change. The terminal operations officer or the dispatcher sets the time and frequency of observation before and during the batch change. The suggested procedure is to begin taking readings 20 minutes before the expected arrival time of the interface. The samples should be taken at five-minute intervals. Beginning five minutes before the expected arrival time, samples are taken each minute. When the interface arrives, samples are taken at the rate of two or three per minute. When samples are taken at intervals of one minute or less, the sample line may be left open and flowing. This ensures representative samples during the actual change.

MAKING THE CUT

The terminal operations officer or the dispatcher issue instructions for making a cut. They are based on the pattern shown in Table 8-1. The sampler watching the batch change is the key person in the operation. When the time comes, the sampler or an assistant operates the valves to make the cut.

Table 8-1. Recommended cut points

BATCH CHANGE	CUT POINT
From MOGAS to JP-4	At first good gravity for JP-4
From JP-4 to MOGAS	At last good gravity for JP-4
From JP-4 to kerosene	At first good gravity for kerosene
From kerosene to diesel	At last good gravity for kerosene
From diesel to kerosene	At mid-gravity
From MOGAS to kerosene	At first good gravity for kerosene
From diesel to diesel	At mid-gravity point
From diesel to MOGAS	At last good gravity of diesel

From MOGAS to diesel	At first good gravity of diesel

BATCH CHANGE RECORDS

Observation of gravity changes for reporting passage of interfaces or for making delivery cuts is based on displacement meter readings or time intervals and on hydrometer readings. The time of the first and last gravity reading and the rate of flow should be reported to the dispatcher. This information fixes the exact time the interface passes. It also shows the length and volume of the interface. The format of the batch change record is prescribed by the chief dispatcher. Suggested formats are shown in Figures 8-4, page 8-5, and 8-5, page 8-7. In both cases, the first reading recorded is the last reading taken before the first change is noted.

DISPLACEMENT METER AND HYDROMETER

Figure 8-5, page 8-7, is an example of a batch change record based on displacement meter and hydrometer (gravity) readings. The batch change is from gasoline (64° API or 0.7136 specific gravity) to kerosene (42° API or 0.8155 specific gravity). The purpose of the change is to make a heart cut delivery when the interface has passed the take-off point. The change covers a specific gravity range of .1019 (.8155-.7136). Line temperature is 38°F. Gravity has been observed at 1-barrel intervals. Volume and composition of the interface are computed as follows:

- Specific gravity increased 10 points in the first 10-barrel increment (meter reading 371,590 barrels). Specific gravity 0.7136 represents pure gasoline, and specific gravity 0.8155 represents pure kerosene. Therefore, a 10-point increase represents 10/1,019 x 100 = 1.0 percent kerosene (0.10 barrel) in the first increment.

- Gravity increased 2 points in the second increment for a total increase of 36 points. Therefore, the second increment has 36/1,019 x 100 = 3.5 percent kerosene (0.35 barrel).

- The percent of total gravity increase and the corresponding amount of kerosene are computed in like manner for each increment.

- Based on gravity alone, the nineteenth 10-barrel increment has 99.6 percent (or 9.96 barrels) of kerosene and the last of the gasoline. The total of the barrel column shows 115.97 barrels of kerosene in an interface of 190 barrels. The interface has 61 percent tail product and 39 percent head product.

- The flash point tests show that even when good kerosene gravity has been reached, enough gasoline stays to lower the flash point of kerosene to a dangerous level. The 100 barrels added before the cut is a safety precaution that was taken to remove this hazard.

- Figure 8-6, page 8-8, is a graphic showing the same batch change. Point A is the beginning of the interface at a meter reading of 371,580 barrels. Point B is the approximate end of the interface at a meter reading of 371,770 barrels. Point C is the cut point at a meter reading of 371,870 barrels. Area D represents the volume of gasoline in the interface. Area E represents the volume of kerosene as determined by gravity.

Station: Petersburg, VA Date: 18/11/XX Line Temperature: 38°F

FROM:
Product: Gasoline Batch No 4-25
Gravity: API 64.0 Specific 7136
Time of first change: 0329

TO:
Product: Kerosene Batch No 5-20
Gravity: API 42.0 Specific 8155
Time of last change: 0355

Samples

Note: The first sample recorded is the last taken before the first change.

Number	Meter Reading	Observed Gravity	True Gravity	Specific Gravity	Percent	Barrels
1	371.580	64.0	66.8	7136	0.0	0.00
2	590	63.7	66.5	7146	1.0	0.10
3	600	63.1	65.8	7172	3.5	0.35
4	610	62.3	65.0	7201	6.4	0.64
5	620	60.9	63.5	7256	11.8	1.18
6	630	58.5	61.0	7351	21.1	2.11
7	640	55.6	58.0	7467	32.5	3.25
8	650	53.4	55.7	7559	41.5	4.15
9	660	50.6	52.8	7678	53.2	5.32
10	670	48.1	50.2	7788	64.0	6.40
11	680	45.7	47.7	7896	74.6	7.46
12	690	43.9	45.8	7981	82.9	8.29
13	700	42.7	44.6	8035	88.2	8.82
14	710	41.9	43.8	8072	91.9	9.19
15	720	41.4	43.2	8100	94.6	9.46
16	730	40.9	42.7	8123	96.9	9.69
17	740	40.6	42.4	8137	98.2	9.82
18	750	40.5	42.3	8142	98.7	9.87
19	760	40.4	42.2	8146	99.1	9.91
20	770	40.3	42.1	8151	99.6	9.96
21	780	40.2	42.0	8155	100.0	10.00
22	790	40.2	42.0	8155	100.0	10.00
23	800	40.2	42.0	8155	100.0	10.00
24	810				100.0	10.00
25	820				100.0	10.00
26	830				100.0	10.00
27	840				100.0	10.00
28	850				100.0	10.00
29	860				100.0	10.00
30	Cut 870				100.0	10.00

CUT 100 barrels after pure kerosene arrived

RATE OF FLOW 400 BPH TIME: 0355

Figure 8-5. Batch change record based on displacement meter and gravity readings

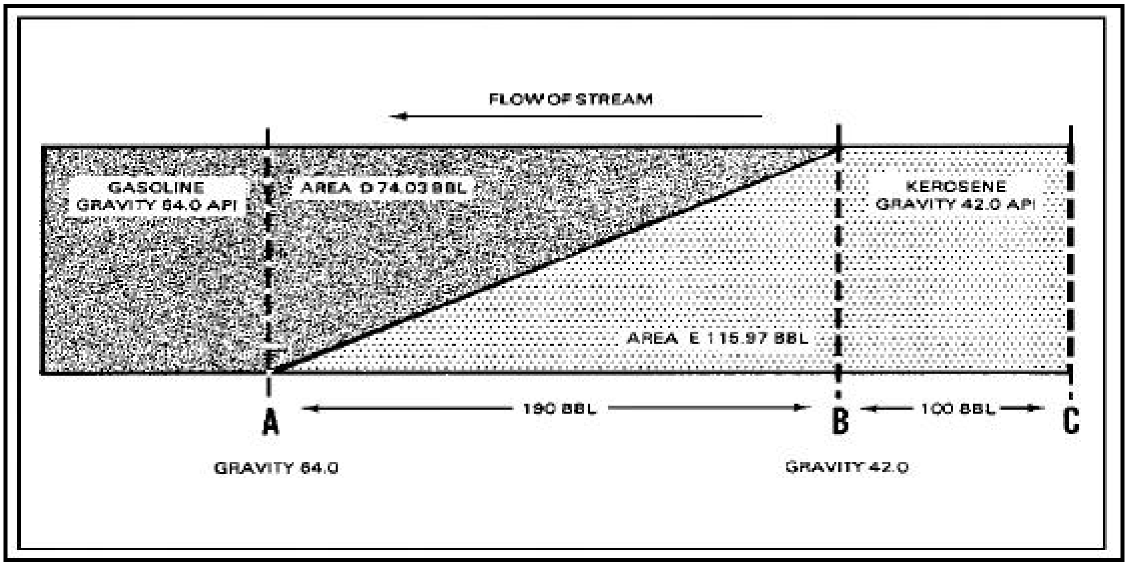

Figure 8-6. Graphic showing a batch change

MID-GRAVITY POINT

Figure 8-5, page 8-7, shows a sample mid-gravity cut point. The mid-gravity cut point is reached in the eighth 10-barrel increment at a meter reading of 371,660 barrels. While percentages vary, mid-gravity cuts divide interfaces into two unequal parts. The smaller part next to the head product consists mainly of head product. The larger part next to the tail product consists mainly of tail product. Because the gravity of the tail part is heavier than the gravity of the head part, the tail product tends to penetrate the head product. The ninth 10-barrel increment has 53.2 percent (or 5.32 barrels) of tail product. The barrel column totals 17.10 barrels of tail product at this point. Therefore, the 80-barrel part of the interface that would go to tail product tankage has 98.87 barrels of tail product and 11.13 barrels of head product. A mid-gravity cut is mentioned for gasoline and kerosene for illustration only. Such a cut would not be made in practice. It would be necessary to protect the octane number and the vapor pressure of the gasoline and the flash point of the kerosene.

TIME INTERVAL AND HYDROMETER

Figure 8-4, page 8-5, shows a batch change record based on observation of gravity for a fixed time interval of one minute. The batch change shown is from kerosene (42.0° API) to gasoline (60.7° API). Readings could have been recorded the same way as in Figure 8-5, page 8-7, to compute the volume and composition of the interface. This record is adequate for recording the passage of an interface or for a cut when the interface has passed.

ANALYSIS OF BATCH CHANGE REPORT

Data recorded in Figure 8-4, page 8-5, can be made to show the same kind of information as that shown in Figure 8-5, 8-7. The information in Table 8-2, page 8-9, has been computed as follows:

- The gravity differential is 61.2 - 42.3 = 18.9°.
- The first gravity change is at 2019 and the final change is at 2040. This is a period of 21 minutes. At 2,800 barrels per hour, the interface has a volume of 980 barrels. This is about 46.7 barrels arriving each minute.
- Percentage and volume of gasoline are computed for each increment as in Figure 8-5, page 8-7.
- The total amount of gasoline in the interface is 560.85 barrels. This is 57.2 percent of the tail product as compared with 61 percent of the tail product in Figure 8-5, page 8-7.

Table 8-2. Analysis of batch change report

Time Taken	Corrected Gravity	Gravity Increment	Total Increase	Percent Gasoline	Barrels
2017	42.3	0.0	0.0	0.0	0.00
2019	42.5	0.2	0.2	1.0	0.47
2020	42.8	0.3	0.5	2.6	1.21
2021	43.6	0.8	1.3	6.8	3.18
2022	44.5	0.9	2.2	11.1	5.18
2023	45.5	1.0	3.2	16.9	7.90
2024	46.6	1.1	4.3	22.7	10.70
2025	47.8	1.2	5.5	29.0	13.54
2026	49.0	1.2	6.7	35.5	16.58
2027	50.2	1.2	7.9	41.8	19.52
2028	51.4	1.2	9.1	48.1	22.46
2029	52.6	1.2	10.3	54.4	25.40
2030	53.8	1.2	11.5	60.8	28.39
2031	55.0	1.2	12.7	67.1	31.34
2032	56.1	1.1	13.8	73.0	34.09
2033	57.0	0.9	14.7	77.7	36.29
2034	57.9	0.9	15.6	82.5	38.53
2035	58.7	0.8	16.4	86.7	40.49
2036	59.5	0.8	17.2	91.0	43.60
2037	60.1	0.6	17.8	94.1	43.94
2038	60.6	0.5	18.3	96.7	45.15
2039	61.0	0.4	18.7	98.9	46.19
2040	61.2	0.2	18.9	100.0	46.70
Total gasoline in interface ……………………………………………………………..560.85 bbl					